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THE USE OF UPPER AIR THICKNESS PATTERNS IN GENERAL FORECASTING

The Monday evening discussion on April 19, 1948, was devoted to upper air thickness patterns and was opened by Dr. R. C. Sutcliffe:—

I have chosen this subject for the meeting not because I shall be able, in the limited time allotted to me, to give a statement of any important new discoveries but because I believe it will prove a stimulating subject for discussion. Routine upper air analysis using isobaric contour charts is a relatively modern departure in our service but in case any forecaster present imagines that it is the latest discovery in synoptic meteorology it should be recalled that the fundamental principles were available in text-book form as long ago as 1910. In Part I of " Dynamical meteorology and hydrography ", V. Bjerknes discussed the subject in some detail and gave examples of synoptic charts at 100-mb. intervals to 300 mb. with both absolute and relative topographies; the word " thickness " was here introduced. So far as I know the introduction into routine aerology came first in Germany some years before the recent war; we adopted the technique in 1941, and in 1947 the International Meteorological Organization agreed to recommend the system for world-wide use.

The chart of relative topography, or thickness chart, with which I am now especially concerned represents by isopleths (thickness lines) the geopotential height difference between standard isobaric surfaces. With the hydrostatic assumption, which is one of the most justifiable among the many approximations used in synoptic meteorology, the thickness is a function only of the (virtual) temperature distribution in the vertical air column; it is, in fact, strictly proportional to the average specific volume of the column. Thus the lines are for practical purposes mean isotherms.

Probably most of us have gained familiarity with thickness charts in the step-by-step construction of upper contour charts and it is sometimes stated that we obtain, say, the 700-mb. chart by adding, graphically, the 1000 to 700-mb. thickness to the 1000-mb. contours. Actually this is a very loose description of the process; rather do we work simultaneously with the relative and absolute contours which are mutually adjusted to ensure the best over-all consistency with the observations. It is sometimes argued that where observa-

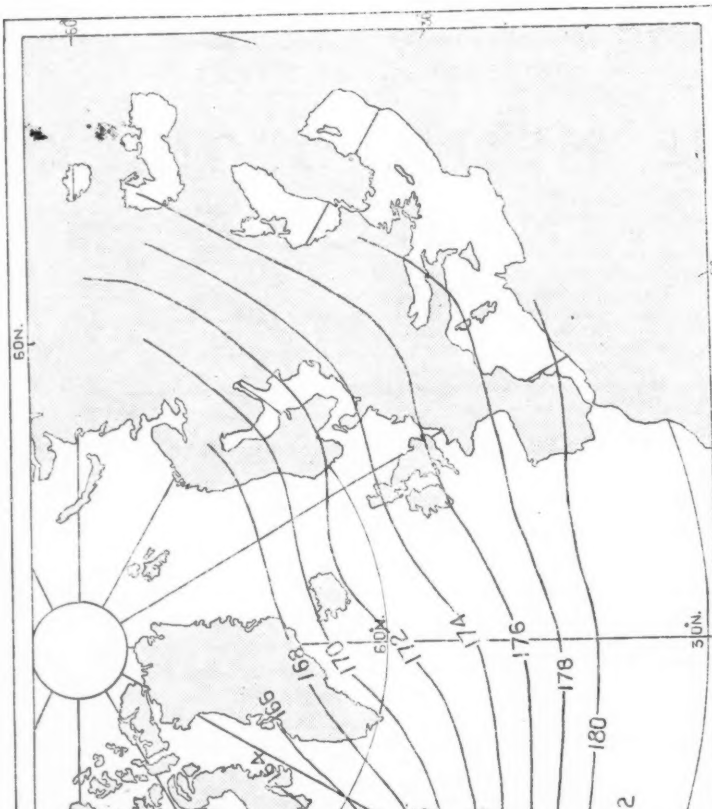

FIG. 1—MEAN THICKNESS IN JANUARY 1948 OF THE 1000 TO 500-MB. LAYER IN HUNDREDS OF FEET

tions are numerous and the network adequate it is a waste of time, in a busy office, to bother with thickness charts when the total contours can be constructed directly with equal accuracy. I have no quarrel whatever with this argument but even if the only object is to construct contour charts it must be pointed out that in a forecast service it is necessary to prepare charts for which, in the nature of the case, there are no observations whatever: I allude to the predicted charts or "prontours". In this connexion the closeness of the observational network is almost an irrelevancy. It may of course be further agued that prediction techniques can be developed without attention to thicknesses but here I would join issue. The variation in the thickness pattern is solely dependent on temperature variations and these variations are restricted by physical processes: advection, adiabatic changes and non-adiabatic processes (radiation, conduction and turbulence), including the phase changes of water under one or other heading. The forecast thickness pattern must be consistent with the possible changes of temperature by these processes and it seems to me most desirable to keep this aspect of things in the forefront. Theoretical considerations set limits to the temperature changes which are possible by the several processes, and research in these matters is going on in this country and elsewhere. It is possible to translate the theoretical results into terms of thickness changes and so ensure that the three-dimensional prediction, as represented by the selected prontour charts, is hydrostatically reasonable. By this means, at least one property of the atmosphere is taken care of in the forecasts.

Not only may the problem of thickness changes be approached theoretically but it may also be attacked empirically using for the purpose the technique which is developed for forecasting. I will indicate what I have in mind by illustrations from the 1000 to 500-mb. thicknesses. In Fig. 1 are given the mean thickness lines for the month of January 1948. Such charts are now available for the last eighteen months and may be used by the routine forecaster in judging to what extent the current temperature field is abnormal. Another form of representation is given in Figs. 2, 3 and 4 which show on one map all the positions taken up by a selected thickness line on the morning charts of one month. Similar diagrams have been drawn for four selected lines for each of the eighteen months and will continue to be prepared as a routine for some time to come. The grossly asymmetric run of the lines with reference to the pole is very graphically displayed as well as the northern and southern limits of their displacements. The charts illustrate no new principles of synoptic climatology, the fact that cold outbreaks sweep well south over the American continent but are modified by the warm sea over the Atlantic is common knowledge, but the charts do show the fact in a graphic form and in terms of the upper-air analyst's parameters. Months and years differ but the essential climatic tendencies remain and it is my hope to present the results in a form which can be of real practical assistance to the routine forecaster, enabling him to predict the movement of each thickness line with allowance for the geographical areas, the season of the year and the synoptic situation even though he may not be able to allow quantitatively for radiation, conduction, convection, subsidence, etc., as distinct physical processes. What the relative importance of these processes is I cannot say definitely; it must vary of course with circumstances, but I think the available theory and synoptic evidence point to non-adiabatic processes being

regularly as important as advective and adiabatic changes. It is sometimes suggested that for short periods of time the non-adiabatic processes can be neglected. This may be true when exceptionally large changes are taking place as in the vicinity of a moving front or depression but, in the area covered by a forecast weather map, such special regions have but limited importance. I cannot believe that the southern limit of the thickness lines, such as is shown in Fig. 2, is invariably or even normally due to the subsidence of southward moving cold air; nor do I believe that the northern limit of warm air is always due to the occluding process. The atmospheric changes are, I believe, even from the daily forecasting standpoint, not even approximately adiabatic, a fact which, if it is true, makes quantitative forecasting, solely on the basis of the equations of motion and present conditions, an impossibility. One may rather visualise a non-adiabatic tendency for an abnormal thermal pattern to relax towards the norm, a conception which could have great importance in forecasting and which could well be incorporated in a thickness technique but only indirectly in a total-contour technique.

But I wish to emphasise that I do not advocate the thickness technique merely as an aid in ensuring hydrostatic consistency in the forecasting of contour charts. It is also an end in itself in that it affords a thermal picture more graphic than a system of isotherms at various levels. We see at a glance where the air is cold or warm, the positions of the cold or warm tongues or pools and where the gradients and curvatures are large or small. If one likes to think in terms of solenoidal concentration in the vertical section the thickness chart gives this precisely. I do not know whether there are still any meteorologists who think that the troposphere is divided into quasi-uniform air masses separated by a polar front in which are concentrated, within a zone of a few hundred miles, the major temperature differences. If so he will find it something of a strain to reconcile his view with synoptic experience of thickness charts. On the hemispherical scale, fronts (unless one multiplies them out of recognition) seem often to appear as interesting local features holding within their grasp but a small bundle of solenoids, significant, but not dominant in the general development problem. As all fundamental theory places temperature in a prominent place it seems unwarranted that its field representation should take second place to isobars or contours; thickness patterns go a long way to redress the balance.

I have still a further plea. In a paper, recently published, I have given theoretical arguments for linking the dynamical development of the circulation systems with the thickness patterns. The value of the results, to me, does not lie in the degree of reliability of the detailed theory but in the encouragement it affords to trying to develop practical empirical rules relating movement and development with thickness and contour or pressure patterns, and in a form suited to routine forecasting. I cannot go into this subject now but I may say that we are directing our attention to thickness gradients and curvatures and especially to the variations of these quantities. Theory suggests that the third derivatives of temperature are all-important.

My advocacy of thickness patterns is thus based on several arguments which I may summarise as follows:—

(*a*) they are a safeguard in contour analysis, and especially in contour forecasting, against the introduction of hydrostatic inconsistencies;

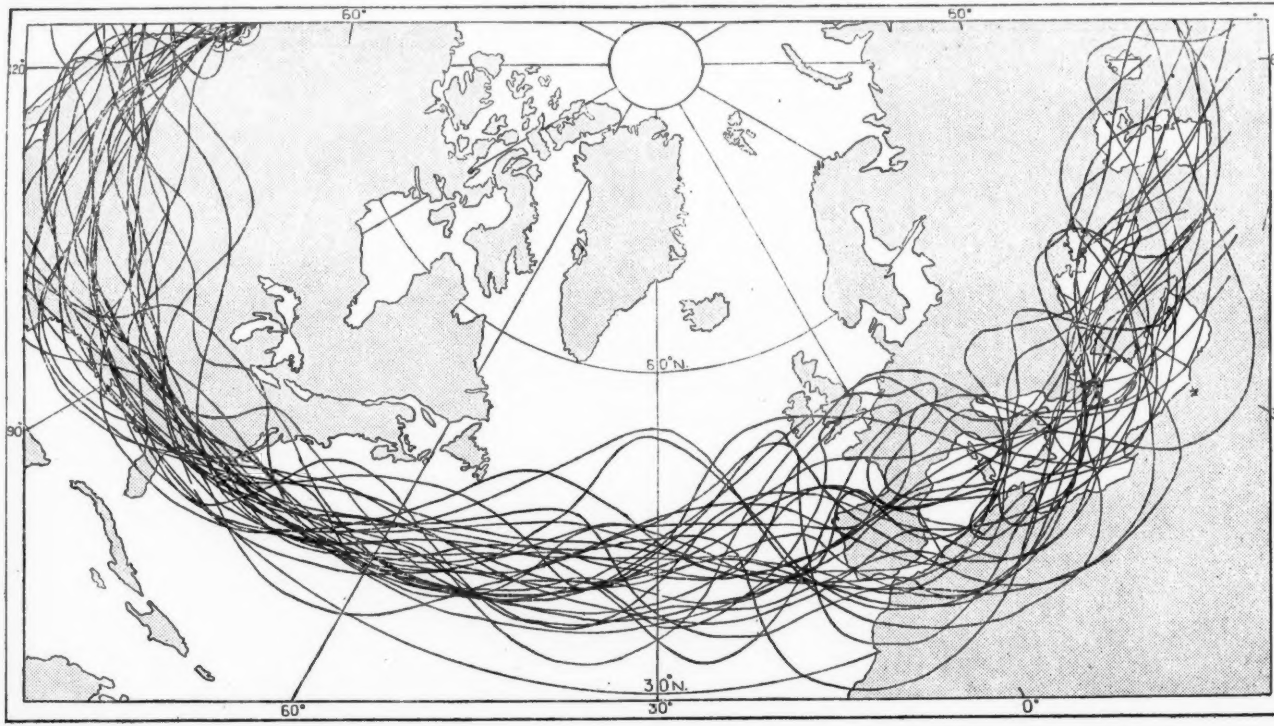

FIG. 2—COMPOSITE CHART OF 18,000-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948

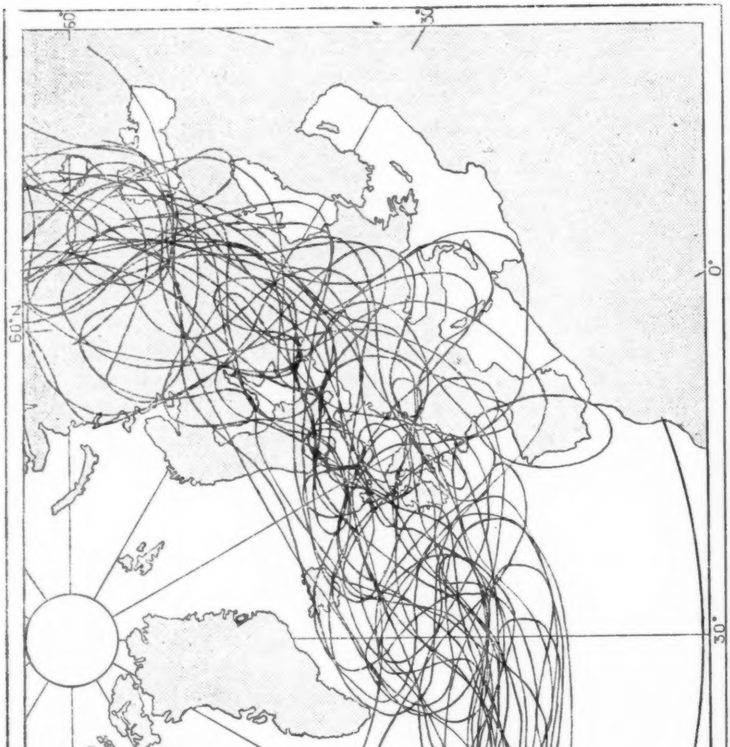

FIG. 3.—COMPOSITE CHART OF 17,400-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948

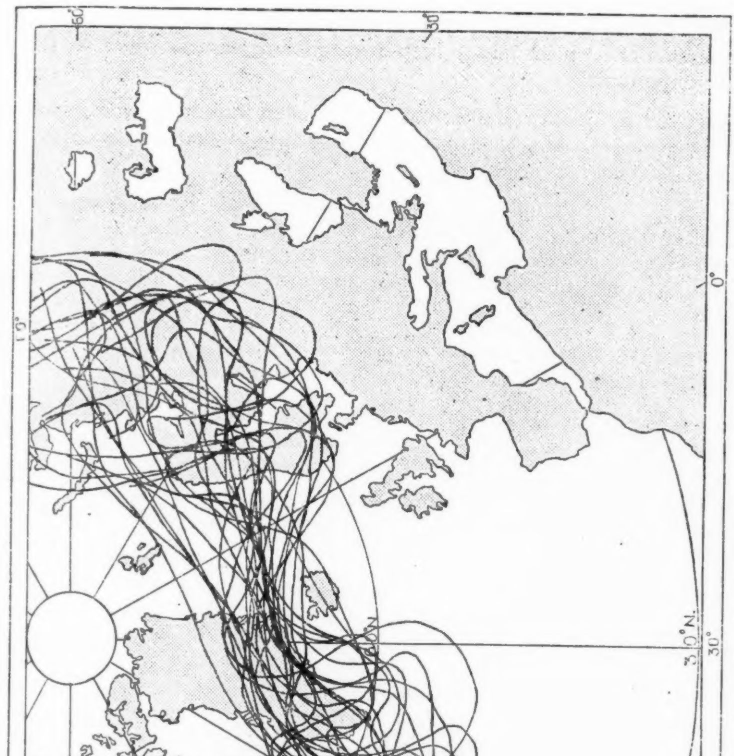

FIG. 4—COMPOSITE CHART OF 16,800-FT. THICKNESS LINE FOR EACH MORNING OF JANUARY 1948

(*b*) they give a good general picture of the temperature field and an accurate representation of solenoids and so keep in the picture features which we know must be important;

(*c*) they aid in air-mass and frontal analysis often indicating which surface fronts are of major and which of minor significance in the large-scale three-dimensional circulation pattern;

(*d*) in a sequence of charts they indicate the changes in the temperature field and give prominence to non-advective processes, so affording the basis for a technique which will be *thermodynamically* reasonable, air-mass modifications, major frontogenesis and frontolysis and the occluding process are also indicated;

(*e*) they afford a promising basis for progress in dynamical analysis and the forecasting of development in the pressure-circulation patterns.

I was once publicly accused of fanaticism about thickness charts. Let me then admit that I do not believe that synoptic meteorology has yet provided itself with a set of isopleths which can be of so much value to the forecaster as a set of well chosen thickness lines; but, as no one likes to be called a fanatic, I will concede, if reluctantly, that there is still something to be said for the mean-sea-level isobars.

It will be said that the system is inadequate; we must have total contours for winds and dynamical analysis, isotherms for temperature forecasting, charts of the tropopause topography, a multitude of tephigrams for stability studies, humidity charts, cross-section diagrams, frontal-surface topographies, hodographs, isentropic charts, constant-vorticity trajectories, and special charts for the study of dynamical instability. There is no end to the aids. But there is an end to the powers of the human brain. Until we develop totally new techniques, with or without electronic brains, we must continue with the system which demands that the forecaster shall be in a position to make a mental model of the synoptic situation. A limited technique, albeit incomplete, may if efficiently used be more successful than an over-elaboration however theoretically admirable.

Sometimes one may hear it provocatively argued that all the modern ideas of meteorology with their impressive techniques have made little impact on the accuracy of the 24-hr. or 48-hr. forecasts. There are competent forecasters ready to claim that they can do just as good work with their surface charts carefully analysed and calmly considered. This is an over-statement, but it is not irrelevant to recall that the technique of frontal analysis, introduced some thirty years ago, won over its adherents with remarkable speed. This was not because the Norwegian model of depressions was theoretically satisfying, indeed the theoretical basis was rather strikingly inadequate, but because it placed in the hands of the forecaster a tool which he could use, one adapted to his particular needs—so much so, that some analysts now force the atmosphere to suit their tool. I regard the thickness patterns as providing another general-purpose tool suited to the work of a forecasting office and I believe it is possible to develop a workmanlike technique.

R. C. SUTCLIFFE

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Photograph by R.A.F.

CLOUD SHADOWS ON SEA AND LAND

Cumulus cloud over the French coast, looking south-east from 18,000 ft. over 51°00′N. 1°50′E. at 1102, June 27, 1944.

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Photograph by R.A.F.

CLOUD SHADOWS ON CLOUD

A broken layer of altocumulus above a layer of stratocumulus. Photograph looking north-east from 28,000 ft. over 52°44′N. 8°00′E. at 1440, October 27, 1944.

SEVERE STORMS OF JULY 2-4, 1946

During the afternoon of July 2 and the night of July 3–4, 1946 many parts of England, east of a line from the Solent to the Humber, suffered severe damage by rain, hail and wind associated with thunderstorms of tropical intensity. Isolated outbreaks of a similar character occur in most years but this particular series was remarkable for the size of the area involved, as well as for the damage caused.

The area principally affected by the storms of July 2 covered west Suffolk and the adjoining parts of Norfolk and Cambridgeshire. A second area over Lincolnshire appears to have been affected more uniformly on a somewhat lower scale. In both areas the period of maximum activity was between 1200 and 1500 G.M.T., though storms continued over a wide area well into the evening.

On the 3rd, thunderstorms broke out over a wide area of eastern England and north France in the late evening, with maximum intensity, as regards this country, in the Farnham-Basingstoke district around midnight, and in west Suffolk and Norfolk 1 to 2 hours later. Very high lightning frequencies were reported, mostly in the clouds, indicating that these were typically high-level storms.

Synoptic situation.—At 0600 G.M.T. on July 1 a depression of moderate intensity with a wide warm sector from Ireland to the Azores was centred about 55°N. 25°W. and moving slowly north-east. An anticyclone over France was giving way to a developing instability trough over the south-eastern half of the Bay of Biscay. Thunderstorms broke out during the day in the neighbourhood of the instability trough, on which a separate circulation had formed, by evening, centred in the Bay of Biscay. By 0600 on July 2 the Biscay low was centred near the Channel Isles and moving east-north-east. The circulation remained feeble but can be followed on the synoptic charts via the Straits of Dover to Holland and Hanover by 0600 on the 3rd. Isolated thunderstorms probably associated with it were reported from Kent at 0900 G.M.T.

The severe storms which occurred over East Anglia and Lincolnshire appear to have been a separate development in the slack gradient to the north of the instability low. Rain reported in the Bristol area at 0900 G.M.T. spread rapidly north-east, increasing in intensity, and by 1200 heavy thunderstorms were in progress over much of Cambridgeshire, Huntingdonshire, west Suffolk, south-west Norfolk and Lincolnshire. During the afternoon and early evening (see Figs. 1 and 2) practically the whole of eastern England between the Thames and the Humber became affected to some extent. Separate surface circulations with strong local winds formed over the main storm areas, but in view of the generally south-westerly gradient aloft there is nothing to suggest any direct connexion between the mid-morning storms of Kent and the Dover Straits and the later storms of East Anglia.

During the night of the 2nd–3rd the cold front of the Atlantic depression moved eastwards across the northern North Sea, and by 0600 extended from north-east England to a wave west of Brittany. The frontogenetic nature of the storms of the 2nd was clearly indicated by a cold front from just west of Holland to the western Pyrenees, with a wave over Normandy on which a circulation developed during the day with a movement corresponding to the upper air current. The storms of the night of the 3rd–4th were widespread

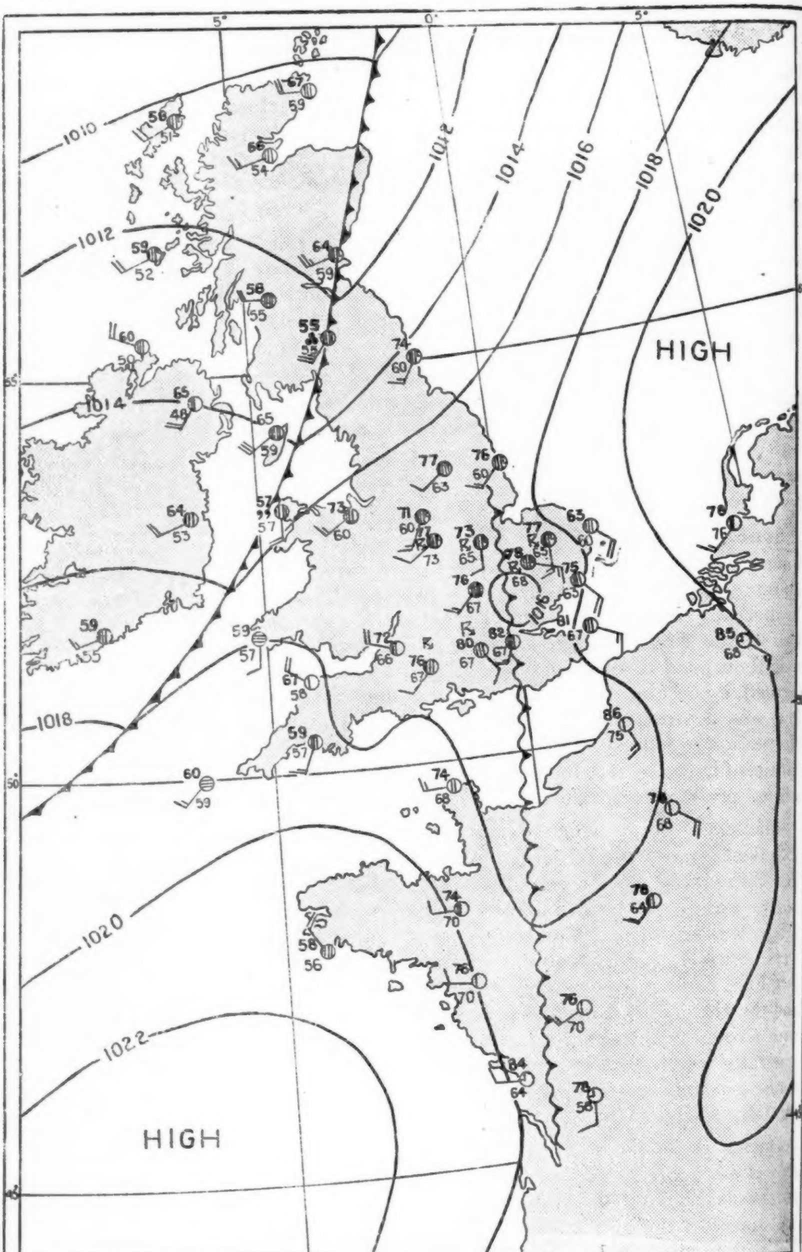

FIG. 1—SYNOPTIC CHART FOR 1200 G.M.T., JULY 2, 1946

Bold figures represent dry-bulb temperatures, thin figures represent dew-point temperatures; other symbols have their usual meaning.

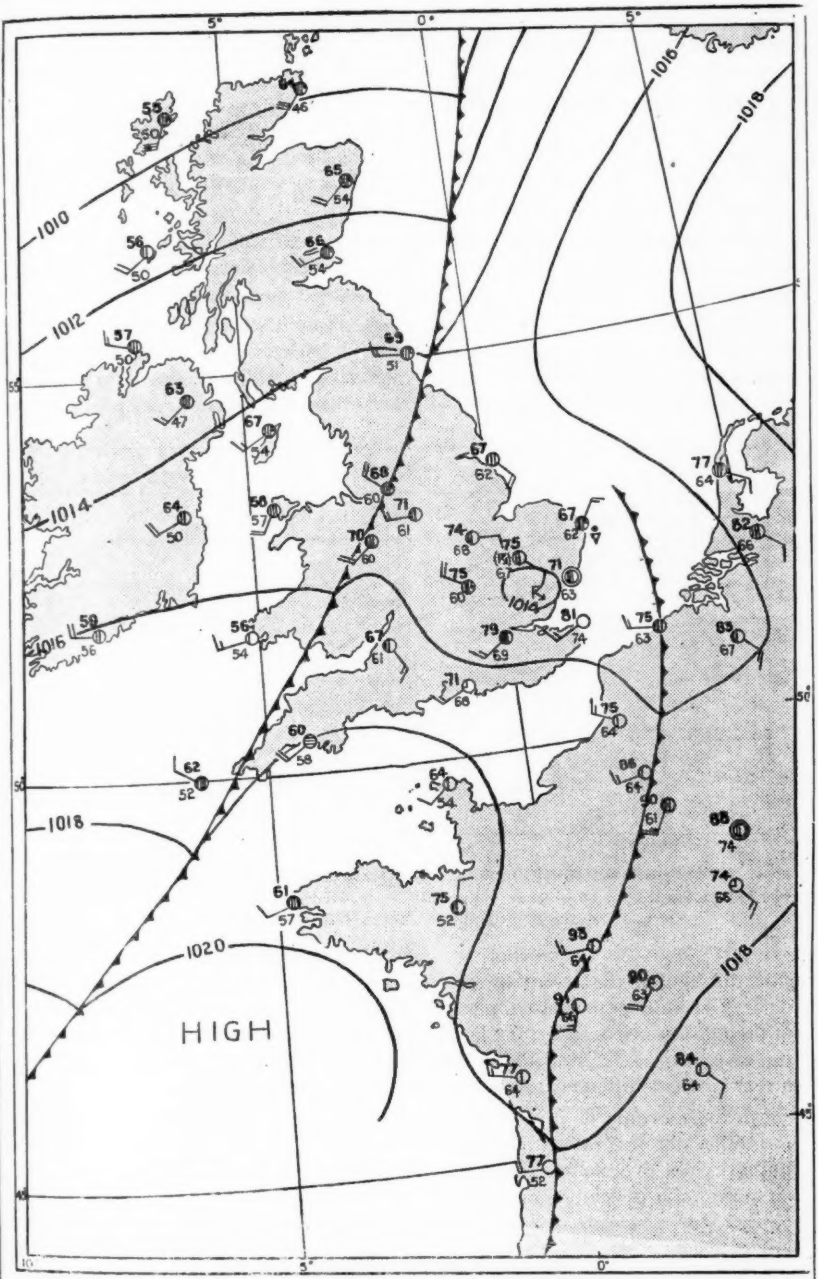

FIG. 2—SYNOPTIC CHART FOR 1800 G.M.T., JULY 2, 1946

Bold figures represent dry-bulb temperatures, thin figures represent dew-point temperatures; other symbols have their usual meaning.

both in this country and on the nearby continent and were most severe on the warm front of the depression.

Upper air conditions, July 2-3.—*Temperature.*—Larkhill (0000) and Downham Market (0600) on the 2nd showed strong similarities as regards temperature and moisture content, with freezing level 650 mb. (12,000 ft.) and a lapse rate unstable for saturated air above 800 mb. (7,000 ft.), but the air was not saturated at 450 mb. (20,000 ft.).

Between 0000 and 0600 at Larkhill, advection of warmer and drier air took place above 450 mb. (20,000 ft.). This had been foreshadowed by the veer and increase in winds above 500 mb. (18,000 ft.) on the midnight ascent.

The midday ascent at Downham Market was made in rain after thunderstorms had broken out in the district and convection had already carried much moisture into the upper layers. Relative humidity was over 80 per cent. at nearly all levels and the lapse rate unstable for saturated air up to at least

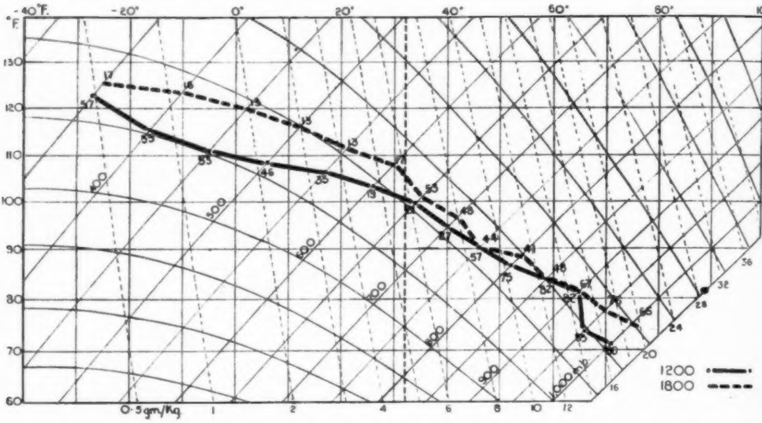

FIG. 3—TEPHIGRAM OF UPPER AIR ASCENTS OVER LARKHILL, JULY 2, 1946
The figures are the values of relative humidity calculated with respect to water above freezing point, and with respect to ice below freezing point.

500 mb. (18,000 ft.), with slightly stable saturated air above. The mean lapse rate throughout the ascent to 350 mb. (30,000 ft.) was very nearly along the 65°F. wet-bulb potential-temperature curve. By evening, after the cessation of the main storm activity, the lapse rate had settled down to slightly more than the saturation value and the fall in wet-bulb potential temperatures indicated a real air-mass difference associated with frontogenesis.

On the morning of July 3 the 0600 Downham Market ascent again showed instability for saturated air above 800 mb. (7,000 ft.), and as the relative humidity was over 80 per cent. up to 500 mb. (18,000 ft.), conditions were highly favourable for developments of intensity comparable to the previous day. The tendency was accentuated by advection from France of very warm air in the lower levels.

Figs. 3 and 4 illustrate the upper air temperatures at Larkhill and Downham Market at the time of maximum activity on the 2nd.

Tropopause, July 1–3.—The height of the tropopause throughout the period was in the region of 39,000 ft., with some irregular features:—

(i) A fall to 37,000–37,500 ft. on the 1st.

(ii) A rise to about 41,500 ft. on the 2nd.

(iii) A rise to 44,500 ft. at Larkhill on the midnight ascent of the 2nd–3rd, not shown at Downham Market.

Upper winds and electrical disturbance.—July 2.—Before the storms, winds were fairly uniform at 200° 20 kt. up to 700 mb. (10,000 ft.), veering and increasing with height to 270–290° 35–40 kt. at the tropopause. During the storm period winds in the higher levels backed to 240°, increasing to 60 kt., subsequently becoming 210–230° 30–40 kt.

Although the Downham Market midday ascent was made in rain and one of the most violent storms was then in progress 15 miles to the south-east, there was no indication of local winds associated with the storm centre.

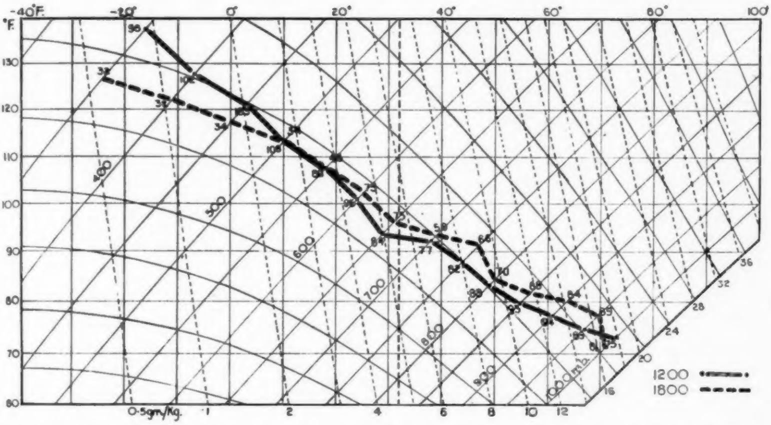

FIG. 4—TEPHIGRAM OF UPPER AIR ASCENTS OVER DOWNHAM MARKET, JULY 2, 1946

The figures are the values of relative humidity calculated with respect to water above freezing point, and with respect to ice below freezing point.

Observations of atmospherics made between 0800 and 2115 G.M.T. were unfortunately interrupted at the time of maximum activity between 1300 and 1730. As far as can be judged from the chart of plotted areas of activity (Fig. 5) the spread was at first in accordance with the winds below 700 mb. (10,000 ft.), but subsequently became more in agreement with the winds at higher levels. The drift of the storms in Suffolk agreed substantially with the low-level winds of 200° 15–20 kt., while over Lincolnshire the direction of movement seems to have been in agreement with the winds between 10,000 and 20,000 ft., i.e., about 250° 20–25 kt. The explanation may be that the former were essentially low-level and the latter high-level storms.

July 3.—Winds were generally light south-easterly up to 850 mb. (5,000 ft.) Above this level the direction became steady at 200–220°, speed increasing gradually with height to 50–60 kt. at the tropopause. No observations of atmospherics are available for the storms of the night of the 3rd–4th.

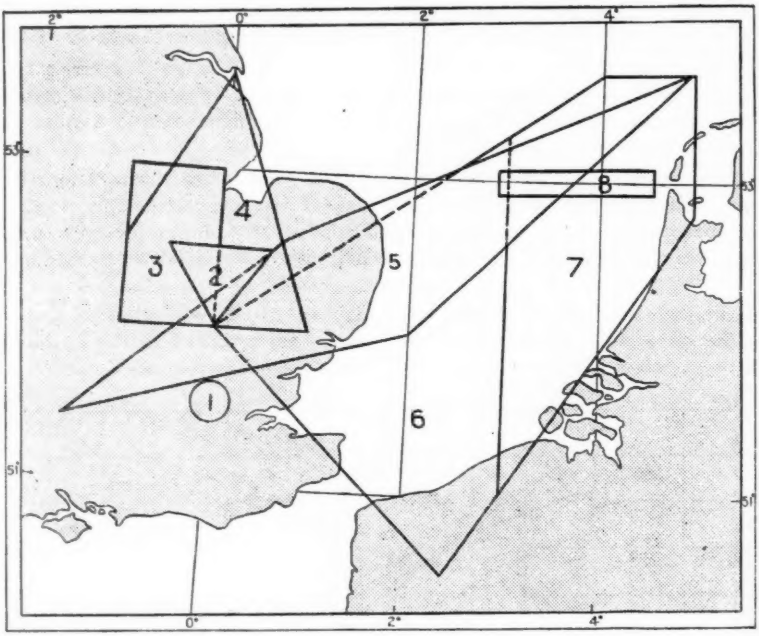

FIG. 5—DIAGRAM SHOWING THE AREAS AFFECTED BY ATMOSPHERICS DURING VARIOUS LISTENING PERIODS ON JULY 2, 1946

Period	Time	No. of observations	Period	Time	No. of observations
1	0800–0815	1	5	1730–1745	9
2	1030–1045	3	6	1845–1900	5
3	1120–1135	4	7	2000–2015	7
4	1300–1315	9	8	2100–2115	3

No observations were possible between 1315 and 1730 G.M.T.

Local reports.—The storms received a good deal of publicity at the time, but a number of reports from experienced observers have been received, from which the following will serve to emphasise the exceptional nature of the events described.

July 2.—*Mildenhall, Suffolk.*—There were three distinct storm periods, namely 1200–1230, 1400–1500 and 1700–1800 G.M.T., with a total precipitation of 1·58 in. The most severe damage was caused during the first phase, in a mile-wide belt from the Cambridgeshire border near Soham to south-west Norfolk between Brandon and Thetford. Two observers mention funnel clouds at the time. In some parts whole fields of growing crops were so completely destroyed as to be unrecognisable. Numbers of poultry were killed or blinded by the hail, which accumulated to a depth of 15 in. in drifts and lay still unmelted next morning, when it was seen being shovelled out of a tradesman's yard. At Mildenhall the recorded wind reached 26 kt. for a quarter of an hour, with a maximum gust of 41 kt.

Tuddenham, Suffolk.—There were two major storms, at 1130–1230 and 1430–1530 G.M.T., the latter being the more severe. This storm passed directly over the airfield and the wind, which reached 26 kt. at times, completely boxed the compass. Very heavy hail measuring up to 1 in. in diameter and torrential rain fell, causing local flooding and interrupting telephone and teleprinter communications.

Marlingford Hall, Norfolk.—There was a brief but intense storm lasting only 5 min. at 1400 G.M.T.; 0·64 in. of precipitation fell in the form of hailstones which measured up to $1\frac{1}{4}$ in. in diameter half an hour after the storm; 168 panes of glass were broken in one greenhouse.

Bury St. Edmunds, Suffolk.—At Westley 2·36 in. of hail and ice fell, causing much damage to crops.

Hawley Green, Stowmarket.—Precipitation exceeded 2 in. It is interesting to note that 10 to 15 miles to the south of Bury St. Edmunds and Stowmarket precipitation was negligible or absent.

Cromer, Sprowston and Santon Downham.—Here also, very large hail, $\frac{3}{4}$–1 in. in diameter, and serious crop damage was reported.

Coningsby, Lincs.—Between 1300 and 1400 G.M.T. a most severe storm occurred, accompanied by rain of tropical intensity with wind of gale force estimated up to 70–80 kt. in squalls. An Anson aircraft was blown a distance of 200 yd. from its chocks, and a lorry was blown against a Lancaster. A corrugated-iron hut was blown a distance of 100 yd., smashing 4-in. reinforced posts on the way.

Night of July 3-4.—*Farnham, Surrey.*—There was a violent storm with almost continuous lightning and heavy hail between 2300 and 0100 G.M.T. For about 15 min. the wind reached gale force, flattening hop-gardens and breaking branches from many fruit trees. Hail broke thousands of panes of glass and many roofing tiles. Total fall: 1·3 in. Similar descriptions were received from Churt and Rowledge.

Bramley, Basingstoke.—During a thunderstorm which occurred from 2345–0015 G.M.T. a thatched house in a nearby village was fired by lightning; 0·77 in. of rain was measured.

Margate.—2·16 in. of rain and hail fell during the night.

West Suffolk and Norfolk experienced heavy and prolonged storms, mainly of rain. At Westley (Bury St. Edmunds) 2·75 in. fell, making 5·11 in. within 2 days, causing severe local flooding with water up to bedroom level in the lower part of the town.

Mildenhall.—The thunderstorm between 0100 and 0200 G.M.T. was accompanied by only light precipitation but was followed by variable, mainly moderate continuous rain until 0900 G.M.T., totalling 0·44 in.

Marlingford Hall, Norfolk.—There was a severe storm lasting all night. 1·7 in. of rain were recorded.

Characteristics of hailstones.—As would be expected, descriptions of the form taken by the hail vary considerably. Most commonly they are described as roughly spherical, with some degree of flattening. At Farnham, Surrey, the lesser diameter was only half the greater (see Fig. 6), but in all other cases departure from the spherical appears to have been relatively slight, except where

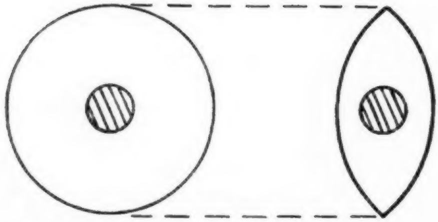

FIG. 6—ACTUAL SIZE AND SHAPE OF THE HAILSTONES OBSERVED AT FARNHAM, SURREY

There is a soft opaque core in the centre surrounded by solid ice; some extra-large stones were rough and of a rectangular crystalline formation.

stones seem to have been fragments of larger spherical or ovoid originals. The "jagged lumps of ice" referred to in some Press reports are not confirmed by any reliable observers, but the explanation may be that where hail lay thickly many smaller stones coalesced.

In general the largest hailstones were about $1\frac{1}{4}$ in. in diameter but some, which fell as irregular pyramids, may have been of greater size before they broke, possibly in mid air.

The structure in most cases consisted of an opaque nucleus surrounded by clear ice, but at Barton Mills, Suffolk, the stones are described as having alternate layers of clear and opaque ice, while at nearby Tuddenham, during the same storm, spherical stones of clear ice $\frac{3}{4}$–1 in. in diameter were observed.

F. W. JUDE

METEOROLOGICAL RESEARCH COMMITTEE

The first meeting of the Instruments Sub-Committee was held on April 29. This first meeting of the Sub-Committee was devoted to reviewing the various instrumental problems which are being investigated in the Meteorological Office.

The first meeting of the Synoptic and Dynamical Sub-Committee was held on May 6. The lines along which the various problems of synoptic and dynamical meteorology in the Committee's programme should be tackled were considered.

The question whether the saturated adiabatic and the humidity mixing-ratio lines on the tephigram should be altered to conform with condensation of water vapour to liquid water, instead of sublimation to ice, at temperatures below 0°C. was discussed but it was decided that present knowledge of the physical processes of condensation and sublimation at sub-freezing temperatures is inadequate to justify a change.

A paper by J. K. Bannon dealing quantitatively with the error involved in the use of the gradient wind as an approximation to the true wind in disturbed conditions was also discussed.

The second meeting of the Physical Sub-Committee was held at the Clarendon Laboratory on May 12. During the morning the Sub-Committee were able to inspect the work in progress, on condensation and sublimation of water vapour, under the supervision of Prof. Dobson. In the afternoon the lines along which this work should be developed were discussed.

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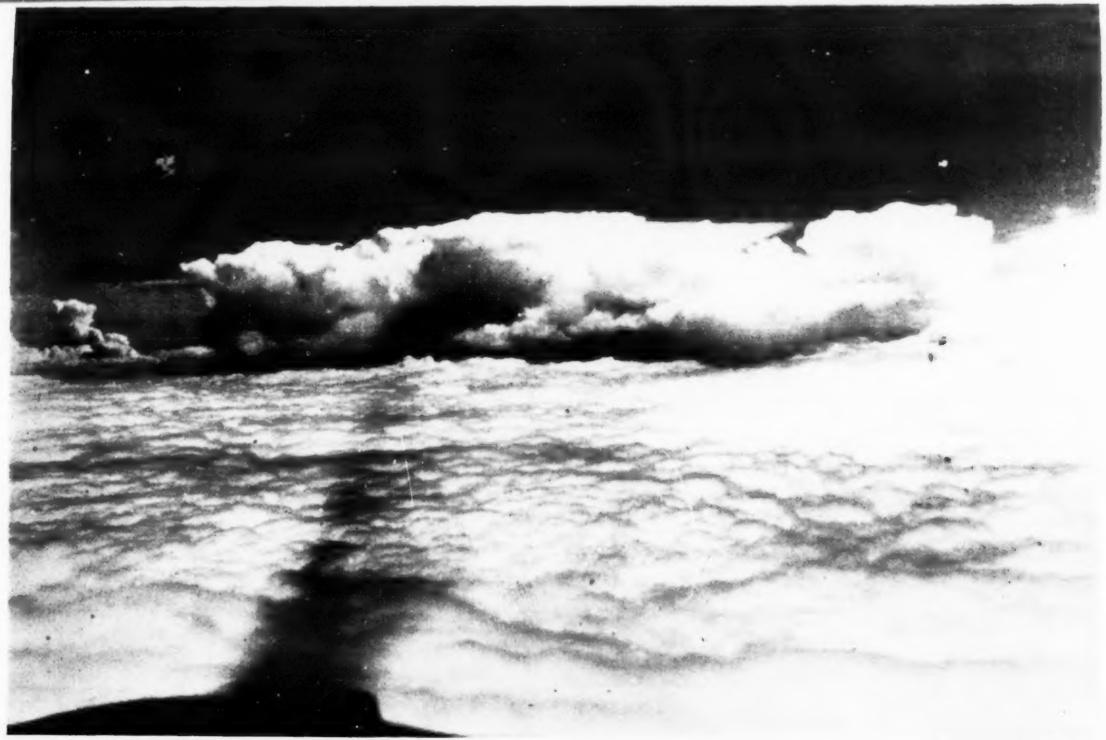

Photograph by R.A.F.

CUMULONIMBUS ANVILS OVER SUFFOLK

There were thunderstorms in the area at about the same time. Photograph taken looking south from 15,000 ft. over 52°40′N. 0°45′E. at 1425, June 1, 1944.

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Photograph by R.A.F.

LARGE CUMULONIMBUS ANVIL IN THE BAY OF BISCAY

Photograph taken looking south-west at 1306, August 8, 1944, from 16,000 ft. over 46°20'N. 2°30'W.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society, held at 49 Cromwell Road, on May 19, 1948, Prof. G. M. B. Dobson, President, in the Chair, the following papers were read:—

J. S. Sawyer—The structure of the intertropical front over N.W. India during the S.W. monsoon.

Opening this paper, Mr. Sawyer drew attention first to the general circulation over north-west India during August. The mean pressure and surface wind flow for this month showed a general trough of low pressure over southern Iran to Afghanistan and north-west India, with an extension down the Ganges valley. The inflow of surface winds into this region could be divided by a line, along the southern coast of Arabia and the north-west frontier of India, between those from the continent and those from the Indian Ocean; this line is the normal surface position of the intertropical front (I.T.F.). Similarly mean upper-wind maps showed the normal position of the I.T.F. to be 400 miles further south at 3 Km. but a shorter distance further south at 6 Km.

Consequently, the I.T.F. might consist of a front sloping one way in the lower levels (up to 10,000 ft.) and sloping the opposite way in the higher levels. This fits in with the known facts that, because of the steeper lapse rate and higher surface temperatures of the continental air, it would be warmer than monsoon air and therefore tend to overlie it in the lower levels, the reverse occurring in the higher levels.

Mr. Sawyer then proceeded, with the help of 700-mb. and 500-mb. pressure surfaces drawn for each day between August 23 and September 1, 1945, using pilot-balloon wind observations and radio-sonde data from several stations in the area, to work out the structure of the I.T.F. on several days. These were illustrated by several slides, some of maps at different levels on the same day and some of tephigrams of the air masses involved, including two showing the " nose " of continental air sandwiched between monsoon air. Also using information gathered from aircrew flying in monsoon conditions, he drew two schematic cross-sections across the I.T.F. showing the different types of cloud and weather likely to be experienced in the region of the I.T.F.

C. A. Wood—Report on the weather of the Borneo-Celebes region, 1946.

In the absence of Mr. Wood this paper was read by Inst. Lt. Cdr. Thorp. It draws attention to the difficulties of forecasting in tropical regions near the equator where even surface observations are very sparse. " Imagination may run riot over thousands of square miles of unrelieved blankness on the chart; surface wind shows a healthy contempt for the isobars, and land and sea breezes become the decisive factors."

The paper describes the weather conditions at Balikpapan which is just over one degree south of the equator and on the east coast of Borneo, facing the Macassar Strait and the island of Celebes. Both Borneo and Celebes are mountainous and the weather is strongly affected by topography.

A major feature was the formation of what were called disturbance lines, orientated east-north-east to west-south-west drifting from the north (over North Borneo ahead of surges of the Asiatic high) from December to March, from the south in March and April, and during the SE. monsoon from May to October. These disturbance lines could be frontal (associated with fronts

LARGE CUMULONIMBUS ANVIL IN THE BAY OF BISCAY
Photograph taken looking south-west at 1306, August 8, 1944, from 16,000 ft. over 46°20'N. 2°30'W.

from the north or the intertropical front) or orographic or convectional or mixtures of all three, but there was no really conclusive evidence. The paper described the conditions observed both on the surface and in the air in some detail, seven of the disturbance lines very fully.

On the whole, the weather at Balikpapan seemed to consist of thundery rain on most days, temperatures between 70° and 90°F., local surface winds (usually modified by land and sea breezes), good visibility (fog did occur on the rare clear nights after a thunderstorm and locally over marshes and in valleys), much convectional cloud (often cumulonimbus and cumulus pileus) and much altocumulus and altostratus, particularly before and after thunderstorms associated with disturbance lines and/or convection.

Opening the discussion, Sir Charles Normand said that most meteorologists in India had been well acquainted with Mr. Sawyer's construction of the I.T.F., particularly the lower part and Dr. Ramanathan had given some idea based on pilot-balloon ascents. Thanks were due to Mr. Sawyer for completing the scheme in some detail. He would like to stress, however, how much convection spoils the picture in tropical regions: fronts are rarely well marked. One thing that had always puzzled him in India was what happened to the monsoon air over India ? It came in from the south and seemed to vanish over India; it could not escape over the Himalayas, or over Burma since air entered India from that direction, or over Afghanistan since air came in from that direction also.

Dr. Forsdyke, in some general remarks, thought there were two main ways in which disturbance lines could be formed in the tropics; (*a*), as remnants of polar fronts for which there was evidence in disturbance lines ahead of surges from the north mentioned by Mr. Wood, and also in the Carribean and called by the Americans easterly waves; (*b*), originating in the tropics as convergence zones with no contrast of temperature. He emphasised that the movement of fronts formed in convergence zones was difficult to forecast since they did not move continually as fronts do in temperate regions. Dr. Forsdyke illustrated the two types by means of slides and, in particular, showing a complicated method of finding convergence zones by studying the wind field at 2 Km., evaluating, plotting and drawing isopleths of $\partial u/\partial x$ and $\partial v/\partial y$ on two charts and then " gridding " them together to show positive and negative areas of the horizontal divergence $\partial u/\partial x + \partial v/\partial y$.

Cdr. Burgess remarked that it had been found that the westerly winds at certain times in Australia could be traced as originating in the NE. monsoon from Asia; thus some of the disturbance lines could easily be frontal. In the tropics sea breeze and land breeze could be quite large, as much as Beaufort force 4 or 5 vector difference from normal, and could be felt over the sea to a distance of up to 90 miles from the coast. Naval vessels had made an investigation with this result near Ceylon. On occasions convergence between land breeze and sea breeze had been noticed which was quite sufficient to cause cloud and possibly rain.

Mr. de Reuck showed two slides of isentropic cross-section and cloud structure across the I.T.F. He had found that in forecasting, account had to be taken of the amount of penetration of dry air. When a new cold front came from the north over north-west India the lower part of the monsoon air in the I.T.F. disappeared altogether.

Cdr. Hogben repeated the plea of Lt. Cdr. Hines who disliked the term convergence applying to regions where winds merely seemed to flow together. Taking wind strength into account this may not be a region of convergence but only a region of what he would like to call confluence.

Mr. Schove mentioned that when he was in British West Africa he had traced a cold front from the Mediterranean right across the Sahara which fitted in with one of what he called, in his note on equatorial weather, " stability fronts ". Such fronts were very similar to Dr. Forsdyke's easterly waves and seemed to move at 30 m.p.h.

Inst. Lt. Cdr. Thorp, speaking on his own behalf, stressed that in the tropics there was an additional coordinate it was essential to bear in mind: the time of day. It was often reliable to forecast from charts of the previous day since the weather seemed to repeat itself. Land and sea breezes were fundamental and he had noticed a land breeze and monsoon vector fall from 30–35 kt. in the morning to 16 kt. in the afternoon. The confluence resulting from a weak monsoon and sea breeze had often resulted in the very rapid development of cumulonimbus over Trincomali harbour; very heavy thunderstorms used to occur there about 1700–1800 for this reason.

ROYAL GEOGRAPHICAL SOCIETY

On May 3, Prof. Ahlmann, the eminent Swedish glaciologist, lectured to the Royal Geographical Society on " The present climatic fluctuation ".

Prof. Ahlmann, in a brilliant lecture, presented an immense array of facts tending to show the existence since the mid-nineteenth century of a world-wide increase of temperature and decrease of precipitation.

An increase in mean temperature during this period has been found by Manley for England, Labrijn for Holland and Ångström for Sweden. Their concordant curves were projected on the screen. The greatest increase of temperature, however, had taken place in the area between Norway, Spitsbergen, and north-east Greenland in which the mean winter temperatures had increased by over 10°C. since 1912. Evidence of increased heat and reduced rainfall was then advanced from the shrinkage of the Great Salt Lake in Utah, U.S.A., which had occurred in the same time.

In Prof. Ahlmann's view an increase in solar radiation leading to an increase in the general circulation must be responsible for these phenomena.

Prof. Ahlmann then turned to his glaciers, whose state gives an integrated picture of temperature and precipitation changes, and pointed out that in all parts of the world, except Antarctica, about which there is little information, they are rapidly receding. From Alaska, Iceland, Greenland, Scandinavia, the Alps and the high mountains of east Africa the story was one of rapid retreat. In Alaska one large glacier was retreating at the enormous rate of 400 m./year. Comparative photographs of some Norwegian glaciers were projected showing very vividly the shrinkage which had taken place. Many Norwegian glaciers had disappeared altogether. As for the Antarctic the only information he had was from a Norwegian expedition which had just returned and reported to him a diminution in the ice cover at a point on the coast. A companion event was the drying up of tropical lakes which had led to some, in east Africa, practically disappearing in the dry season.

Turning now to the ice of the North Polar Basin, over the area in which Nansen, in the *Fram* in 1893, measured an average thickness of ice of 365 cm., the Russian ice breaker *Sedov* in 1937–40 found only 218 cm. Ships were now able to reach Spitsbergen during 7 months of the year compared with only 3 months in the early part of the century. Russian reports stated that the ice in the Russian Arctic waters shrank by 1 million sq. Km. between 1924 and 1942.

Important biological consequences of the warming of the Arctic were that cod were now to be found up to 73°N. on the Greenland coast, 1,000 Km. further north than in earlier years, that the birch trees of northern Norway which between 1875 and 1915 produced good seed in only two years now produced it almost every year, and that the annual rings of northern trees were getting thicker.

This decrease in the amount of glacier ice might be expected to have an important practical consequence in a gradual rise of sea level. According to Gutenberg the rise at present was only of the order of 1 mm./year. If, however, the Antarctic and Greenland ice caps, which between them contained some 90 per cent. of all the ice in the world, started to shrink at the same rate as the small glaciers the rise in sea level might assume serious proportions. How much the level might rise was not very certain but there was evidence in New Guinea and Australia that the last ice age caused a fall of 90 m. in sea level.

Prof. Ahlmann concluded by pointing out the immense scientific and practical interest of this climatic fluctuation as the first which mankind had the opportunity of following scientifically. In his opinion, the Antarctic held the key position and an expedition to it, to be specially devoted to glaciology, was urgently necessary. In addition to glaciological investigations, radio-sonde observations ought to be made along the meridian from the Antarctic through Graham Land over South and North America and also over Africa.

The full account of Prof. Ahlmann's lecture in the *Geographical Journal* will be eagerly awaited.

LETTER TO THE EDITOR

London temperatures and the mercury-in-steel thermograph

In his interesting article on London temperatures in the March issue of the *Meteorological Magazine*, Mr. Marshall stated that the Bourdon tube of the mercury-in-steel distant-recording thermograph at the Meteorological Office is exposed in a Stevenson screen on the roof of Victory House. It is, of course, the bulb of the instrument which is exposed in the screen; the Bourdon tube forms part of the recorder which is installed inside the building.

Mercury-in-steel thermometers consist essentially of three parts, the bulb, the connecting tube and the Bourdon tube, all made of steel and welded together to form a closed system which is filled with mercury under pressure. The bulb, which is about 10-in. long and $\frac{5}{8}$-in. diameter, is nickel-plated and then copper-plated for protection against corrosion. The Bourdon tube is flat in section and is coiled into a spiral, one end of which is attached to the spindle of the recorder pen arm. Expansion of the mercury due to increase in temperature of the bulb causes the spiral to uncurl and so moves the pen. No backlash occurs since the Bourdon tube itself acts as a spring. The capillary tubing connecting the bulb and the Bourdon tube may be as much as

150 ft. long but if lengths of more than 20 ft. are used, compensation for the effect of the capillary being at a different temperature from the bulb is provided by enclosing a certain volume of invar steel, which has a very low coefficient of expansion, into the capillary. The mercury-in-steel thermograph is one of the most reliable distant-recording thermometers available for meteorological purposes.

May 12, 1948 F. J. SCRASE

NOTES AND NEWS

Mr. John Dover

It was with great regret that we heard that Mr. John Dover, M.A., had decided, because of his advancing years, to give up his meteorological work at his home in Totland Bay, Isle of Wight. Mr. Dover began taking meteorological observations at Totland Bay in 1886. His rainfall observations were first sent to the British Rainfall Organization in 1888 and they have been published in *British Rainfall* since 1890. Full climatological returns were sent to the Meteorological Office in 1904 and summaries have been published in the *Monthly Weather Report* from 1904 onwards. In 1940, after Mr. Dover had supplied meteorological records for 52 years, the Director of the Meteorological Office presented him with an aneroid barometer in appreciation of his long voluntary service.

Mr. John Dover is a keen and experienced climatologist and has produced each year an exhaustive annual report, which contains not only a description, with a summary, of the observations of the year in question but also long-period averages of each of the elements and details of extremes of pressure, wind, temperature, rainfall and sunshine. In past years Mr. Dover paid occasional visits to the Meteorological Office and has always been pleased to co-operate in any way, such as supplying specific information for his station over a long period of years. Mr. Dover has therefore made a definite contribution to our knowledge of the climate of Totland Bay.

We wish Mr. Dover much future happiness and ask him to accept our sincere thanks for his long and accurate series of climatic observations.

HONOURS

The Birthday Honours List, June 1948, announced the appointment of Dr. C. E. P. Brooks, Assistant Director Climatology of the Meteorological Office, to be a Companion of the Imperial Service Order.

WEATHER OF MAY 1948

Depressions were centred over or near to the British Isles from the 1st to the 5th. An anticyclone then spread from the south-west, and pressure was generally high for four days. On the night of the 9th, the anticyclone having withdrawn to Scandinavia and northern Russia, a shallow depression began to move northwards from France, and lay over the North Sea until a new anticyclone advanced from the Atlantic on the 12th. Pressure was generally high over the British Isles from the 13th until the last few days of the month, except in the south during the passage of depressions on the 23rd and 26th, but became generally low on the 31st when a depression was centred over the Irish Sea. A striking feature of the maps for the last part of the month was the frontal system which extended across the subtropical Atlantic from Cuba to Spain. Depressions with central pressures as low as 996 mb. formed on this system

over the Azores between the 20th and 22nd and south-west of Bermuda between the 24th and 26th.

For the month as a whole pressure exceeded 1020 mb. near the Azores. Over Europe and the western part of North America, and from Norway to Greenland, pressure was generally not more than 3 mb. above or below 1015 mb., and was for the most part within 3 mb. of the average.

The weather over the British Isles was distinguished by a notable excess of sunshine. Cool unsettled weather occurred at the beginning of the month and from the 22nd onwards but the intervening period was warm.

The first four days were cool and unsettled with rain at times and local thunderstorms on the 1st and 2nd. Subsequently a belt of high pressure extended from the south-west of Ireland across the British Isles to the White Sea and fair weather prevailed during the 6th–9th. Thereafter a spell of rather unsettled thundery weather ensued until the 13th. On the 14th a large anticyclone moved north-east over the British Isles to the North Sea and on the 19th and 20th a new anticyclone moved south-east from a position north-west of Iceland; warm fair weather, with abundant sunshine, prevailed until the 21st. By the 22nd pressure was highest over Greenland with a wedge extending south to the west of Ireland and cool polar air brought a considerable fall of temperature to northern districts of the British Isles on the 22nd and to southern districts on the 23rd. Subsequently cool unsettled weather was re-established and persisted until the end of the month. Local thunderstorms were reported daily from the 24th to the 31st.

The warm spell around the middle of the month was noteworthy; temperature reached or exceeded 80°F. at a number of stations in the period 17th–19th. On the other hand low screen minima were registered locally at times, particularly on the 1st, 2nd, 3rd, 24th and 25th.

The rainfall distribution was variable; in Scotland more than the average was confined to eastern districts from the Moray Firth to the Firth of Forth, while more than twice the average occurred locally in Angus and at Inverness. In England and Wales, broadly speaking, more than the average occurred south-east of a line from the Humber to Carmarthenshire. More than 200 per cent. occurred over much of an area extending from Norfolk across the Cotswolds to west Dorset.

The general and substantial excess of bright sunshine was a notable feature of the weather of the month. At numerous stations it was the sunniest May on record.

The general character of the weather is shown by the following table:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	82	22	+0·2	116	−3	129	50
Scotland	84	21	+0·2	77	−2	135	46
Northern Ireland ..	78	26	−0·2	80	−6	132	47

RAINFALL OF MAY 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	2·77	157	*Glam.*	Cardiff, Penylan ..	4·01	164
Kent	Folkestone, Cherry Gdns.	1·84	110	*Pemb.*	St. Ann's Head ..	1·81	90
"	Edenbridge, Falconhurst	2·75	148	*Card.*	Aberystwyth	1·04	50
Sussex	Compton, Compton Ho.	3·51	158	*Radnor*	Bir. W. W., Tyrmynydd	4·59	134
"	Worthing, Beach Ho. Pk.	1·70	103	*Mont.*	Lake Vyrnwy	3·39	100
Hants.	Ventnor, Roy. Nat. Hos.	2·74	161	*Mer.*	Blaenau Festiniog ..	3·27	58
"	Bournemouth	2·01	114	*Carn.*	Llandudno	·91	51
"	Sherborne St. John ..	2·93	151	*Angl.*	Llanerchymedd ..	2·01	86
Herts.	Royston, Therfield Rec.	2·96	153	*I. Man.*	Douglas, Boro' Cem. ..	2·60	104
Bucks.	Slough, Upton ..	2·95	176	*Wigtown*	Port William, Monreith	·92	39
Oxford	Oxford, Radcliffe ..	4·96	265	*Dumf.*	Dumfries, Crichton R.I.	2·33	85
N'hant.	Wellingboro', Swanspool	3·08	159	"	Eskdalemuir Obsy. ..	1·77	54
Essex	Shoeburyness	1·35	104	*Roxb.*	Kelso, Floors	1·33	69
Suffolk	Campsea Ashe, High Ho.	1·37	91	*Peebles.*	Stobo Castle	2·16	95
"	Lowestoft Sec. School ..	2·32	144	*Berwick*	Marchmont House ..	1·87	76
"	Bury St. Ed., Westley H.	3·44	189	*E. Loth.*	North Berwick Res. ..	1·34	67
Norfolk	Sandringham Ho. Gdns.	4·22	231	*Midl'n.*	Edinburgh, Blackf'd. H.	2·34	114
Wilts.	Bishops Cannings ..	3·92	201	*Lanark*	Hamilton W. W., T'nhill	·95	40
Dorset	Creech Grange.. ..	2·26	111	*Ayr*	Colmonell, Knockdolian	·95	37
"	Beaminster, East St. ..	4·57	222	"	Glen Afton, Ayr San. ..	1·57	52
Devon	Teignmouth, Den Gdns.	2·35	128	*Bute*	Rothesay, Ardencraig ..	1·70	56
"	Cullompton	4·01	186	*Argyll*	L. Sunart, Glenborrodale	1·79	50
"	Barnstaple, N. Dev. Ath.	2·15	104	"	Poltalloch	1·24	43
"	Okehampton, Uplands	2·64	98	"	Inveraray Castle ..	2·96	75
Cornwall	Bude School House ..	2·24	122	"	Islay, Eallabus ..	1·20	45
"	Penzance, Morrab Gdns.	3·00	136	"	Tiree	1·73	69
"	St. Austell, Trevarna ..	2·26	93	*Kinross*	Loch Leven Sluice ..	3·08	126
"	Scilly, Tresco Abbey ..	1·84	100	*Fife*	Leuchars Airfield ..	2·58	132
Glos.	Cirencester	4·70	228	*Perth*	Loch Dhu	2·76	61
Salop	Church Stretton ..	2·13	84	"	Crieff, Strathearn Hyd.	2·12	85
"	Cheswardine Hall ..	1·70	77	"	Blair Castle Gardens ..	..	..
Staffs.	Leek, Wall Grange P.S.	1·22	49	*Angus*	Montrose, Sunnyside ..	3·21	157
Worcs.	Malvern, Free Library	2·90	134	*Aberd.*	Balmoral Castle Gdns..	3·46	149
Warwick	Birmingham, Edgbaston	2·48	116	"	Dyce, Craibstone ..	3·44	135
Leics.	Thornton Reservoir ..	2·52	125	"	Fyvie Castle	2·92	113
Lincs.	Boston, Skirbeck ..	2·91	165	*Moray*	Gordon Castle	1·92	91
"	Skegness, Marine Gdns.	2·80	165	*Nairn*	Nairn, Achareidh ..	2·38	134
Notts.	Mansfield, Carr Bank	2·17	102	*Inv's*	Loch Ness, Foyers ..	3·78	55
Ches.	Bidston Observatory ..	1·14	60	"	Glenquoich	..	..
Lancs.	Manchester, Whit. Park	1·10	52	"	Fort William, Teviot ..	1·42	36
"	Stonyhurst College ..	1·51	53	"	Skye, Duntuilm ..	1·49	52
"	Blackpool	1·65	76	*R. & C.*	Ullapool	·99	40
Yorks.	Wakefield, Clarence Pk.	·99	50	"	Applecross Gardens ..	2·30	71
"	Hull, Pearson Park ..	1·95	101	"	Achnashellach	2·92	69
"	Felixkirk, Mt. St. John	1·01	54	"	Stornoway Airfield ..	1·22	50
"	York Museum	1·21	61	*Suth.*	Lairg	2·44	96
"	Scarborough	1·44	75	"	Loch More, Achfary ..	1·72	39
"	Middlesbrough.. ..	1·20	63	*Caith.*	Wick Airfield	1·69	82
"	Baldersdale, Hury Res.	1·46	57	*Shet.*	Lerwick Observatory ..	1·85	89
Norl'd	Newcastle, Leazes Pk.	1·76	89	*Ferm.*	Crom Castle	2·45	88
"	Bellingham, High Green	1·66	69	*Armagh*	Armagh Observatory ..	2·29	96
"	Lilburn, Tower Gdns...	1·24	54	*Down*	Seaforde	3·42	130
Cumb.	Geltsdale	1·39	54	*Antrim*	Aldergrove Airfield ..	1·72	76
"	Keswick, High Hill ..	1·22	38	"	Ballymena, Harryville..	1·28	45
"	Ravenglass, The Grove	1·38	49	*Lon.*	Garvagh, Moneydig ..	1·90	74
Mon.	Abergavenny, Larchfield	3·69	138	"	Londonderry, Creggan	2·03	77
Glam.	Ystalyfera, Wern House	4·16	119	*Tyrone*	Omagh, Edenfel ..	1·39	54

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JANUARY 1948

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
	Mean of day M.S.L.	Diff. from normal	Absolute		Mean values							Total	Diff. from normal	Days	Daily Mean	Percentage of possible
			Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb							
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	998·8	−18·1	56	31	48·2	39·2	43·7	+3·2	41·3	88	7·9	3·57	+1·81	22	1·3	15
Gibraltar	1020·3	−1·2	72	42	62·9	51·9	57·4	+2·5	53·9	91	6·2	7·24	—	16	5·1	51
Malta	1015·7	−1·3	66	44	61·0	51·7	56·3	+1·0	53·9	74	5·0	1·19	—	10	6·6	66
St. Helena	1015·[illegible]	0·0	81	58	71·7	60·0	65·9	+2·2	60·3	96	9·2	2·66	+0·43	17	—	—
Freetown, Sierra Leone	1011·0	+1·7	88	69	84·1	73·1	78·6	−0·2	72·3	80	4·7	0·00	−0·41	0	8·2	70
Lagos, Nigeria ..	1010·7	+1·1	92	60	89·3	68·7	79·0	−1·9	74·1	83	6·0	0·00	—	0	6·0	51
Kaduna, Nigeria ..	1010·7	—	94	55	88·5	58·9	73·7	+0·1	53·8	18	1·9	0·00	0·00	0	8·6	75
Chileka, Nyasaland	101[illegible]·0	−0·1	91	62	83·2	66·9	75·1	0·0	69·5	75	6·4	5·20	−3·39	13	6·6	51
Lusaka, Rhodesia ..	1010·0	+0·2	87	59	78·7	62·9	70·8	+0·1	65·3	81	7·8	7·78	−2·57	20	4·9	—
Salisbury, Rhodesia ..	1011·0	+0·2	85	55	78·4	60·3	69·3	+0·3	62·5	73	6·2	7·18	−0·53	18	6·5	50
Cape Town ..	—	—	99	51	81·5	61·0	71·3	+1·4	62·1	70	3·1	0·14	−0·54	4	—	—
Germiston, South Africa	1011·0	—	89	51	78·4	57·7	68·1	—	58·2	67	3·8	3·61	—	12	8·7	64
Mauritius																
Calcutta, Alipore Obsy.	1015·7	−0·1	87	54	80·5	58·6	69·5	+2·9	59·5	87	2·4	0·81	+0·39	2	6·7	61
Bombay	1012·4	−1·2	90	61	83·2	68·3	75·7	+0·2	66·0	76	3·7	0·34	+0·24	5	7·6	68
Madras	1013·4	−0·7	85	65	83·5	69·7	76·6	+0·4	70·9	89	4·0	2·16	+1·02	7	8·8	77
Colombo, Ceylon ..	1010·8	0·0	91	70	87·6	72·6	80·1	+0·6	72·0	89	4·8	4·52	+1·27	12	8·3	70
Singapore	1010·8	+0·4	91	71	84·5	73·0	78·7	−1·0	74·8	86	8·1	19·81	+9·92	22	—	—
Hongkong	1021·4	+1·7	75	39	65·7	54·4	60·1	−0·1	54·6	72	—	1·24	−0·08	9	5·6	51
Sydney, N.S.W. ..	1015·2	+2·8	82	55	73·7	61·8	67·7	−3·9	62·6	69	6·1	9·02	+5·35	16	6·7	48
Melbourne	1016·5	+3·6	104	49	77·1	55·3	66·2	−1·2	57·5	58	6·1	1·23	−0·66	9	9·4	65
Adelaide	1017·4	+4·4	110	50	82·8	59·1	70·9	−2·8	59·0	39	3·2	0·14	−0·58	4	11·0	78
Perth, W. Australia	1014·6	+2·1	100	53	85·6	63·1	74·3	+0·5	64·5	48	2·7	0·06	−0·28	2	10·6	87
Coolgardie	1014·3	+2·9	107	53	94·7	64·7	79·7	+2·3	63·5	48	1·9	0·09	−0·37	2	—	—
Brisbane	1012·7	+1·4	88	62	81·8	65·7	73·7	−3·5	66·1	65	5·3	4·78	−1·67	11	8·9	65
Hobart, Tasmania ..	1016·6	+6·3	95	45	69·9	51·7	60·8	−1·2	53·9	58	6·1	1·10	−0·73	11	8·3	56
Wellington, N.Z. ..	1014·7	+1·4	82	50	71·0	57·2	64·1	+2·9	59·3	69	6·2	3·44	+0·11	9	8·1	55
Suva, Fiji	1006·9	−0·6	91	71	86·1	75·1	80·6	+0·7	76·5	85	8·1	7·09	−4·34	24	5·0	38
Apia, Samoa ..	1008·2	+0·3	93	71	86·5	74·6	80·5	+0·4	77·7	81	7·5	17·02	−0·74	25	5·5	43
Kingston, Jamaica ..																
Grenada, W. Indies	1012·6	−0·2	85	63	84·2	73·5	78·9	+1·8	73·5	79	5·7	4·96	+0·58	23	—	—
Toronto	1020·4	+2·5	39	−12	25·5	10·9	18·2	−4·0	15·4	—	7·6	1·57	−1·22	13	3·7	40
Winnipeg	1019·6	−1·3	29	−36	8·4	−9·9	−0·7	+3·2	−3·8	—	5·5	0·59	−0·32	10	3·8	44
St. John, N.B. ..	1014·5	−1·0	39	−9	24·9	9·9	17·4	−1·8	13·9	—	6·5	5·11	+0·31	16	3·0	33
Victoria, B.C. ..	1022·5	+6·5	49	22	43·5	32·9	38·2	−0·8	35·1	90	7·0	4·25	−0·29	14	3·0	34